# Circular Patch Antenna Design using Swine Influenza (H1N1) Characterized Model based Optimization Technique

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*Abstract*—**In this paper, a very fresh optimization technique naming 'swine Influenza model based optimization (SIMBO)' has been explored through the application in the antenna design. The SIMBO with all available variant has been introduced and various aspects have been discussed along with flow chart and algorithm. A proposed technique has been tested by applying for design and optimization of an inset feed circular microstrip patch antenna. An available closed form formula of microstrip patch antenna resonant frequency has been used to form the fitness function in order to optimize the dimensional parameters like radius and feed point location. The input to the SIMBO optimizer is desired resonant frequency and response is dimensional parameters of the antenna in terms of the radius of patch and feed point location on the patch. Antenna has been fabricated in the laboratory and tested experimentally. All results including simulation, computationally calculated and measurement are compared in order to confirm the accuracy of the method.**

***Index Terms*—Swine influenza model based optimization (SIMBO); Vaccination; Pandemic state; Circular micro patch antennas; Polarization; Computer simulation technology (CST).**

## I. INTRODUCTION

The search of effective optimization technique is still going on in order to design microstrip patch antennas based on planar technology. Many vendors have been using theses antennas in various applications like in mobile communications, in point to point communications as ship antennas, in spacecrafts, in missiles, in satellite communications, and in space launch vehicles etc. [1-3]. Few electromagnetic commercial simulators are available in order to design these antennas. These simulators are based on the numerical techniques like Method of Moment (MOM) based IE3D, Finite Element (FE) based HFSS, and Finite Difference Time Domains (FDTD) based CST etc. Though these simulators are being used by researchers and designers frequently, however they are being proved obsolete in later stage due to the various constraints. One of the constraints is that they are time consuming as so many simulations needs to be executed on random basis. Second constraint is that, they require heavy computer resources like high speed processors and large capacity memories. Few vendors of these simulators have already started incorporating optimizer tools like powel optimizer in E3D and PSO in CST etc. Even then users are not comfortable with these tools as these tools are not users friendly and still they require performing many simulations. Therefore, designers are still exploring various computer aided optimization tools that can be applied for fast design especially in real-time applications. Earlier researchers have attempted various softcomputing optimization techniques in antennas design like Artificial Neural Network (ANN) [4-8], Genetic Algorithm (GA)[9-10], Particle Swarm Optimization (PSO)[11-12], Bacteria Foraging Optimization (BFO) [13-15] etc. Recently Swine Influenza model based optimization (SIMBO) has been introduced by the researchers [16-20].

Many researchers from medical field tried to develop various mathematical models and simulated them on high speed computer in order to study the behaviors and pattern of swine flue. In general, virus spread from one location to another location through the traveling of mankind, therefore it was found that, less travelling may drop the virus spread rate. During study of swine flue mathematical model, various parameters which were considered are as follows; time of the year, number of person who may travel between the different locations and people resistant to infections of virus. It was concluded that restrictions on movement between locations may reduce spread of swine flue infections. This is probably due to the~~,~~ fast spreading nature of virus in comparison to some other viruses. Other measures that would alleviate the possibility of the spread of the virus include personal prophylaxis, quarantine, use of vaccines and antiviral drugs.

In the previously published literature, swine influenza details, its characterization and application in various fields have been found [16-25]. A very first attempt was done to formulate the model for influenza with vaccination and antiviral treatment in 2008 [16]. A developed model was consisting a control mechanism by using vaccination and treatment through antiviral. Analytic expressions were derived for the few parameters like basic reproduction number, control reproduction number and the final size of the epidemic. In [17], influenza modeling studies have been reviewed and discussed. How these models can provide insights into the future of the currently circulating novel strain of influenza A (H1N1, swine flu), it has been highlighted. In review article [18], authors have discussed pandemic (H1N1) influenza. The clinical picture in severe cases of pandemic (H1N1) influenza is markedly explored. In [19], a swine influenza inspired optimization algorithm has been proposed through the application in a multimodal function optimization and noise removal. In that, the authors inspired from the SIR model (susceptible, S, infectious, I and recovered, R) of swine influenza to construct the new evolutionary algorithm called SIIO. The inspired algorithm expresses its performance on multimodal function and observed that it is fast in convergence and better in accuracy. Authors of [20] explored SIR mathematical model and developed swine influenza models based optimization (SIMBO); a probability based SIMBO model in three categories namely SIMBO-T, SIMBO-V and SIMBO-Q. Still those models need to be explored for many complex problems in order to achieve an accurate solution. Though in later stage, researchers have applied SIMBO variants in different applications like ECG filtering, design of FIR low pass filter, design of digital FIR filter, design of minimization of operation cost of a micro-grid etc. [21-24], however these need to be explored further for RF and microwave domain. A report published in 2016 [25] analyses SIR epidemiological model of influenza thoroughly.

Since no literature has been found about the application of SIMBO in any type of antennas design. In this paper, a novel method based on the one of the swine flue models; SIMBO-T is proposed. The paper is organized as follows. In Section II the swine influenza model overview has been given. Section III presents the proposed optimizer based on the SIMBO. Section IV presents the design consideration of the circular patch antenna to be optimized through proposed optimizer. Implementation aspects of the optimizer have been discussed in the section V. Section VI, discusses the validation of the proposed optimization methodology through simulation as well as experimental work. Finally, some concluding remarks are provided in Section VII.

## II. OVERVIEW OF SWINE INFLUENZA MODEL

In late 19th century, swine flue was identified as a disease, in which a virus naming influenza was able to infect the human respiratory system. Swine influenza generally infects the respiratory tract in a human body which lead to nasal secretions and a barking-like cough. It diminishes appetite and results in listless behavior of a mankind. It is hard for the human immune system to recognize swine flue, therefore it can create severe infections. Just like other flue which does take place seasonally; swine flue is able to spread among the people through close contact by coughs and sneezes but with a very fast rate and affects many people.

In order to characterize swine influenza, the first mathematical model—was developed by Kermack and McKendrick, called SIR (Susceptible–Infectious–Recovered) model (Fig. 1). In that, population is initially divided into three sections; Susceptible (S), Infectious (I), and Recovered (R). A susceptible case of influenza A (H1N1) virus infection is a person with acute febrile respiratory illness with onset within 7 days of close contact with confirmed case of influenza A (H1N1). Depending on the level of virus infection and the prevalence of infection, infected individual~~s~~ is allowed to proceed from class S to class I . An individual who gets recovered is allowed to move~~s~~ to class R, where individual is considered immune for the future virus infection. The population with one infectious individual is considered susceptible (S). The infectious individual (I) is able to transmit influenza to each of the susceptible individual (S) [20].

SIR model was modified in letter stage as a ‘spatial–temporal influenza model’ for the characterization of swine influenza dynamically. In the basic SIR model, few more stage like seasonality, vaccination, treatment, quarantine and isolation were incorporated. The simplest modifications to the SIR model include inflow and outflow of individuals in to the population, which incorporates vaccination and treatment as shown in Fig. 2. In this model, susceptible individuals (S) were given vaccination and infected individuals (I) were given treatment through antiviral drugs (T). Individuals (S) who were given vaccination are allowed to proceed to class V, where they are considered immune to the virus. While treating infectious individuals (I), they were put in to class T, where their infection was considered reduced.

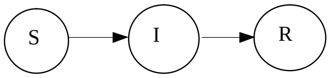


Fig 1. SIR Model.

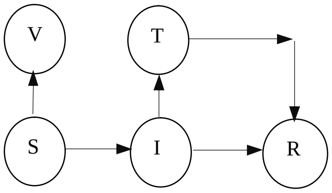


Fig. 2. Extended SIR model incorporating vaccination and quarantine.

Further, SIR model was modified by incorporating two more stages like quarantine and isolation as shown in Fig. 3. In this model, all the susceptible individuals (S) were quarantined ($Q_S$) and then sent back to the original pool of susceptible individuals (S) once it is confirmed they are uninfected. In addition, infected people who are showing no symptoms of virus can be quarantined ($Q_E$). If they develop symptoms and become infectious, they are isolated ($Q_I$), like the infected individuals (I). This development helped to update the developed optimizer.

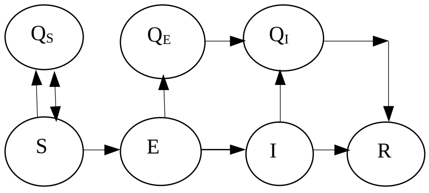


Fig. 3. SEIR model incorporating quarantine and isolation.

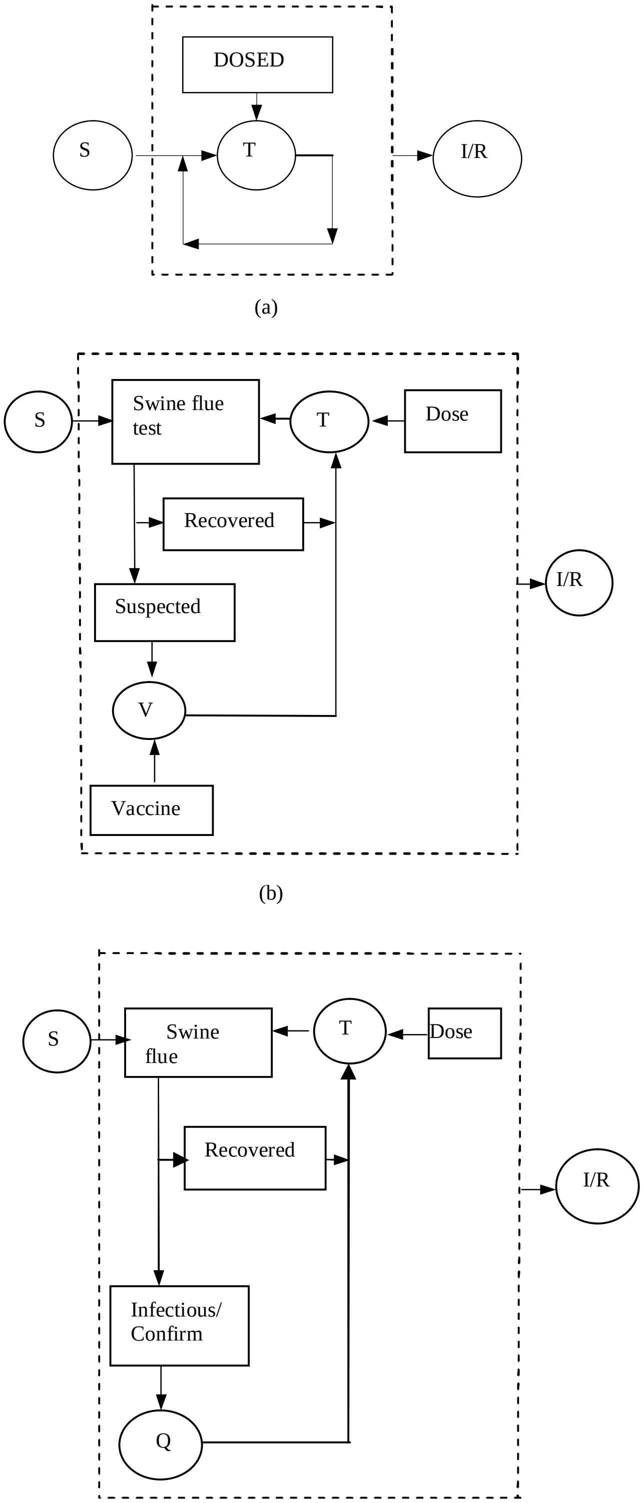
## III. SWINE INFLUENZA MODEL BASED OPTIMIZER

The balance between exploration of the search space and exploitation of potentially good solutions is one of the fundamental requirements in nature-inspired optimization systems. Too much stress on exploration may result in a highly randomized search whereas too much exploitation may lead to trap in a local search. Clearly, intelligent search must dynamically combine exploration of the new regions of the space with evaluation of potential solutions already identified. The proposed SIMBO variants have been proved capable of dynamically combine the exploration and exploitation behaviors in the optimization process [19-20]. The treatment is adjusted dynamically during their optimization process in order to balance the exploration and exploitation trade-off. Dynamic adaptation mechanism enables the SIMBO variants to cope up with complex multimodal search landscapes efficiently.

Taking a clue from the SIR models of swine flue, an optimization technique named as SIMBO-T has been developed and is proposed in this paper. SIMBO variants development has been put light as well. It is an nature inspired evolutionary optimization technique inspired from SIR models of swine flue. The three models of swine flue such as basic SIR, SIR incorporating vaccination and treatment, SIR incorporating quarantine and isolation have been used to develop SIMBO-T, SIMBO-V and SIMBO-Q as shown in Fig. 4 (a)-Fig. 4 (c). The effect of treatment, vaccination and quarantine process was observed during development of these models. It performs the optimization through treatment based on probability. Initially everyone is assumed as susceptible because one infected individual in population leads to total population susceptible. The treatment is given to all suspected cases in the population by varying amount of antiviral drugs depending upon current health. The percentage of antiviral drugs is dependent on primary and secondary symptom as well as current health and pandemic health. As the health of individual deteriorates, dose of the drug increases or additional drug is being added. The SIMBO-T performs optimization through two basic steps: health evaluation and treatment. These two steps will continue until all generations are over. SIMBO-V performs optimization through four steps: health evaluation, swine flue test, vaccination and finally treatment. Similarly SIMBO-Q performs optimization through health evaluation, swine flue test, quarantine and finally treatment. The vaccination protects individuals against disease by putting vaccine in to the body of patient. The vaccine induces immunity in the body. Quarantine involves segregation and isolation of individuals. It restricts free movement of patient to prevent the spread of contagious disease. The segregation of individuals from population is based on swine flue test. The confirmed cases are quarantined from population so that they would attract health of other individuals. The developed SIMBO-T algorithm and flow chart is proposed. The various terms involved are listed in Table I. The pseudo codes for the SIMBO-T have been developed and are in appendix section. On the basis of pseudo codes, source codes can be easily developed on any suitable platform like MATLAB or turbo C.

TABLE I: SIMBO TERMINOLOGY

| Population | Group of individual |
|---|---|
| *TI* | Total number of individuals in population i.e. population size |
| Susceptible individual (*S*) | Initially everyone is assumed as susceptible because one infectious individual in population leads to total population susceptible |
| Recovered individual | The individual cured from swine flue or other viral infections |
| Day (*D*) | Current generation (or iteration) |
| *TD* | Total number of days (or generations) |
| Pandemic state (*PS*) | Pandemic (global) best state amongst all individuals |
| Pandemic health (*PH*) | Fitness value corresponding to pan- demic state |
| Current state (*CS*) | Current state of all individuals |
| Current health (*CH*) | Fitness value corresponding to current state |
| Fever (*Fe*) | Fever refers to an elevation in body temperature. Fever serves as one of the body's natural defenses against bacteria and viruses, which cannot live at a higher temperature |
| Coughh (*Co*) | It is a symptom of other disorders |
| Fatigue and headache (*fathead*) | Fatigue refers to the state of reduced capacity for work following a period of mental or physical activity. Headache is a pain in the head or upper neck. |
| Nausea and vomiting (*NV*) | Nausea and vomiting are symptoms of an underlying disease and not a specific illness. |
| Diarrhea (*Dia*) | Diarrhea is an increase in the frequency of bowel movements or a decrease in the form of stool (greater looseness of stool) |
| Primary (*Day*) | Primary symptom caused per day given as $(Fe * Co * fathead * NV * Dai) * e^{-TD/Day}$ |
| *R0*(*Day*) | The secondary symptom caused per day is given by $\mathrm{R0(Day)} = 1 - e^{(-\mathrm{Primary}(Day))}$ |
| Swine flue test | It is laboratory confirmation of an individual infected with swine flue |
| Vaccination (*V*) | It refers to administration of swine flue vaccination to the susceptible/unexposed population |
| Amount of vaccine (*Vc*) | The dose of vaccine or additional dose given to the individual |
| $\alpha$ | Probability of recovery |
| Momentum factor of dose ($M_d$) | It is used to restrict the dose of individual |
| Momentum factor of state ($M_S$) | It is used to restrict the state of individual |



(a)

(b)

(c)

Fig. 4. Model of (a) SIMBO –T (b) SIMBO –V and (c) SIMBO –Q.

The major steps involved in SIMBO-T model are health evaluation and establish the treatments accordingly. The health of the individual will depend upon given fitness function. Initially, the health of all individuals is evaluated. The patients suspected of swine flue are sampled for confirmation of the diagnosis. The treatment is based on signs and symptoms. Treatment of any disease is often a trial-and-error process. A physician usually initiates the treatment with a standard dose and observes the patients for a response or any side effects. If the response is not sufficient, the drug is increased or changed. On the other hand, if side effect occurs, the dose is decreased or medicine is changed. However, standard strategy of dose is usually based on population dose response characteristics and may not lead to optimal outcomes on individual basis. If the dosing is adjusted over time based on the individual response then optimal outcomes are achieved more quickly. The following steps are involved in SIMBO-T algorithm.

- *Step-1: Define the search space:* Chose the number of parameters which need to be optimized and decide the dimension of space. In case of proposed problem of inset-fed circular patch antenna, radius and feed location are the parameters (2-dimensional problem).
- *Step-2: Define a fitness function:* A fitness function is framed as per the analytical approach using trial-and-modify basis in such a way that it represents the single value of goodness of a solution. For different optimization problem, different search space with different fitness function is to be chosen.
- *Step-3: Initialize SIMBO-T parameters*: *TD, TI,* Co, $Fathead$, $NV$, $Dia$, $M_d$, $M_s$, and $\alpha$ etc. Initially each individual is treated with dose and change in state is determined.
- *Step-4: Update the dose and modify the state:* Each individual is treated by dose and new state of health is determined in a predefined range of search space. Then algorithm acts on each and every individual one by one and covers the whole population.

(a) *Evaluate current health of each individual and pandemic best state amongst all individual and calculate fitness*: The health of individual depends upon given fitness function. Initially, the health of all individuals is evaluated. The fitness value of each individual corresponding to current health and pandemic (global) best state is calculated using Eq. (7). When its current health, found better than its previous health, then reduce the dose. When its current health found better than pandemic (global) best state, dose is reduced.

(b) *Modify the dose:* The dose of the individual is changed as per the current health of each individual and pandemic (global) best state. The dose of the individual is updated as per the Eq. (1).

(c) *Modify the health state of each individual:* After the dose is given, modify its health status as per the Eq. (2).

- *Step-5: Repeat:* After the treatment of each individual, if desired fitness value is achieved then terminate procedure otherwise go to above step and repeat step-4(a) - step-4(c).

In SIMBO-T, the percentage of antiviral drugs depends on primary and secondary symptom as well as current health and pandemic health. For a patient with mild to moderate uncomplicated illness, standard treatment is recommended. For a patient with severe or progressive clinical illness, higher dose treatment may be required. For high-risk patient or whose condition begins to deteriorate, high dose with combination therapy should be promptly initiated without waiting for laboratory confirmation. High-risk patients sometimes do not improve their health because of age underlying conditions. The dose given to the individual is represented by Eq. (1). Due to dose, change in the individual state is given by Eq. (2).

If the health of individual recovers then percentage of dose also decreases or changed. If the current health of individual is near to pandemic health, then second and third terms in Eq. (1) tends to be zero showing that no new dose is required for individual. The flow chart is shown in Fig. 5.

$$\begin{aligned} Dose(m+1) &= DoseM + M_d + \Pr imary(Day) * \\ & rand * (1 - Current\_health(m) / Rand * PH) \\ & + R0(Day) * rand(Current\_health(m) - PH) \end{aligned} \quad (1)$$

$$S(m+1) = S(m) * M_s + Dose(M+1) \quad (2)$$

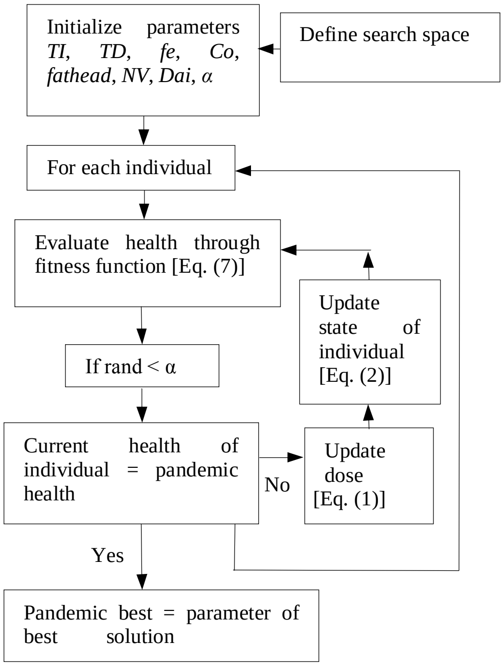

Initialize parameters TI, TD, fe, Co, fathead, NV, Dai, α
Define search space
For each individual
Evaluate health through fitness function [Eq. (7)]
Update state of individual [Eq. (2)]
If rand < α
Current health of individual = pandemic health
No
Update dose [Eq. (1)]
Yes
Pandemic best = parameter of best solution

Fig. 5. Flow chart of SIMBO-T.

## IV. PROPOSED CIRCULAR PATCH ANTENNA GEOMETRY

In order to explore proposed SIMBO-T, a circular microstrip patch antenna has been proposed (Fig. 6). Earlier many researchers have already attempted optimization algorithms on the patch shapes other than circular one [26-28]. Proposed geometry consist of a very thin metallic strip ($t << \lambda_0$ where $\lambda_0$ is free space wavelength) and is placed above a dielectric layer (dielectric constant, $\varepsilon_r = 4.4$) having ground plane at the bottom. The antenna patch has been modeled as a circular shape of radius ($a$) and thickness ($t$) on the substrate (height, $h$) top face with inset feed line of length ($L_f$) and width ($W_f$).

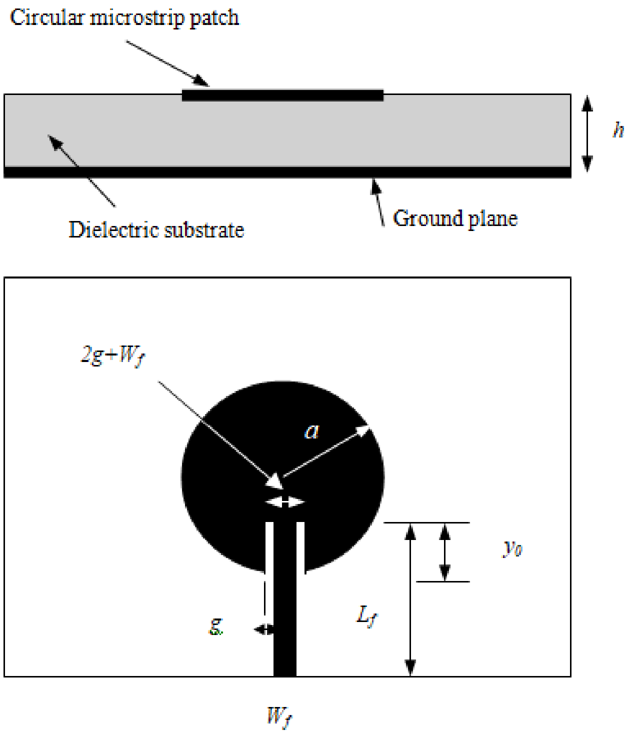


Fig. 6. Circular microstrip patch antenna.

Microstrip transmission line has been used to feed the circular microstrip patch. The feed is inserted deep into the circular radiating element (patch) for the proper impedance matching [1,3]. According to the cavity based model formulation, a designing is proposed for the dominant mode; $TM^{z}_{110}$. The procedure assumes that the specified information includes the substrate dielectric constant, $\varepsilon_r$, the resonant frequency, $f_r$ and height of the substrate height $h$. Since the patch dimension is treated a circular shape, the actual patch radius is given as [3].

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}} \quad (3)$$

Where

$$F = \frac{8.791 \times 10^{9}}{f_r \sqrt{\varepsilon_r}}$$

Eq. (3) does not take into considerations the fringing effect. Since due to fringing effect the circular patch becomes electrically larger, hence the effective patch radius is given by

$$a_e = a\left\{1 + \frac{2h}{\pi a \varepsilon_r}\left[\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{1/2} \quad (4)$$

The resonant frequency is given by

$$(f_r)_{110} = \frac{1.8412\, c_0}{2\pi a_e \sqrt{\varepsilon_r}} \quad (5)$$

Where $c_0$ is velocity of light in vacuum. The input resistance of the antenna for the inset feed is given by [3].

$$R_{in}(y = y_0) = R_{in}(y = 0)\cos^2\left(\frac{\pi}{D_i}y_0\right) \qquad (6)$$

Where $D_i$ (= $2a$) is physical diameter of circular patch. From Eq. (6), the inset depth ($y_0$) can be calculated, where impedance is 50 ohm ($R_{in}(y = y_0) = 50$). The fixed dimensional parameters of the proposed antenna are listed in Table – II. The parameters like radius ($a$ or $a_e$) and inset-depth ($y_0$) are variables.

TABLE II: PROPOSED ANTENNA FIXED PARAMETERS

| S.N. | Different parameters with values | |
|---|---|---|
| | Parameters | Values (mm) |
| 1 | Width of substrate, $W$ | 60 |
| 2 | Length of substrate, $L$ | 60 |
| 3 | Width of inset feed, $W_f$ | 1.86 |
| 4 | Gap for inset feed, ($2g+ W_f$) | 2×0.53+1.86 = 2.92 |
| 5 | Dielectric constant of substrate, $\varepsilon_r$ | 4.4 |
| 6 | Substrate height, $h$ | 0.7 |

From Eq. (6), the maximum value of input resistance occurs at the edge of the slot ($y_0 = 0$), where typical value lies in the range of 150-300 $\Omega$ .The minimum value of input resistance occurs at the center of the circular patch. As the inset feed point moves from the edge to the patch centre the resonant input impedance decrease monotonically and reaches zero at the centre.

## V. SIMBO OPTIMIZER IMPLEMENTATION

The objective of the work is to optimize the geometrical parameters of the inset-feed circular patch antenna operational for any resonant frequency within 8 GHz to 24 GHz. The methodology of optimizer can be understood by Fig. 7. The input to the optimizer is desired resonance frequency ($f_r$ in GHz) and output is geometrical parameters ($y_0$, $a$) of the proposed antenna (in mm). Earlier researchers have associated other parameters like return loss bandwidth or axial ration bandwidth as a input along with resonance frequency [29]. The range selected for optimization of variable parameters is as follows: The circular patch radius; 2 cm to 15 cm, the inset-fed depth 2 cm to 10 cm. Using Eq. (5), fitness function $P$ is developed (Eq. (7)). Optimizer is run and value of radius along with the inset feed depth is calculated. The fitness function has been framed as per the experience. When the calculated resonant frequency matches to its desired value, the value of the fitness function $P$ becomes zero. During optimization, optimizer parameters were set as follows; *Fe* (fever) = 0.4, *Co* (Caught) = 0.4, *fathead* (Fatigue and Headache) = 0.2, *NV* (Nausea and vomiting) = 0.2, *Dai* (Diarrhea) = 0.2, $\alpha$ (probability of recovery) = 0.2, $M_d$ (Momentum factor of the dose) = *rand*, $M_s$ (Momentum factor of health state) = *rand*, *TI* (The size of population) = 15. The optimizer was run for the 1000 generations (total number of days, *TD*). The performance of the optimizer has been evaluated with the plot of average fitness with respect to total number of generations (Fig. 8).

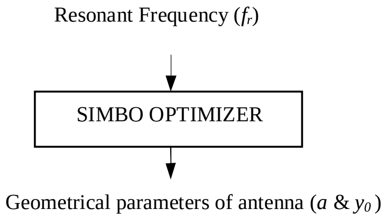

Resonant Frequency ($f_r$)
SIMBO OPTIMIZER
Geometrical parameters of antenna ($a$ & $y_0$)

Fig. 7. Proposed SIMBO Optimizer.

$$P = \left(\frac{(1.84118 * c_0)}{(2\pi a_e\sqrt{\varepsilon_r})} - f_r\right) \qquad (7)$$

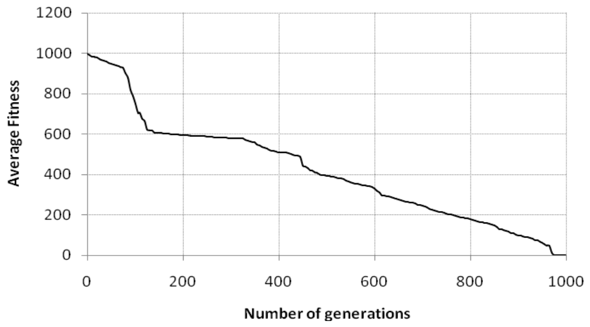


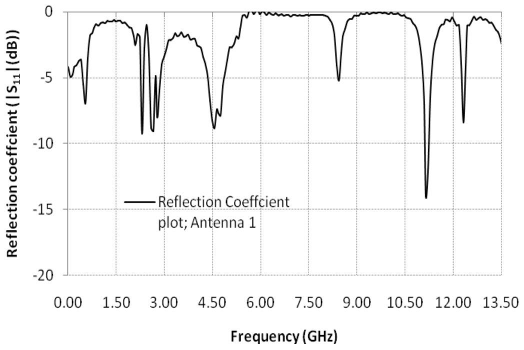
Fig. 8. Average fitness plot.

In the proposed algorithm, to maintain balance between search space exploration and optimum solutions exploitation is a critical task. Because thorough exploration involves random global search whereas too much effort for exploitation of optimum good solutions may results local search. Thorough exploration of search space leads to a large amount of computational time whereas to much effort of exploitation for optimum good solutions leads to an inaccurate solution. Therefore, the treatment has been adjusted dynamically during whole optimization process through the adjustment of dose over the period of time based on the individual response. The quantity of antiviral drugs has been made dependent on the primary and secondary symptom as well as current health and pandemic health. The time varying primary and secondary symptom encourage the individuals to wonder through entire search space during early stage of the optimization rather than clustering around local optima. During the later stages, it enhances the convergence towards global (optima) minima (desired solution). In this way, optimal global solution is achieved more quickly.

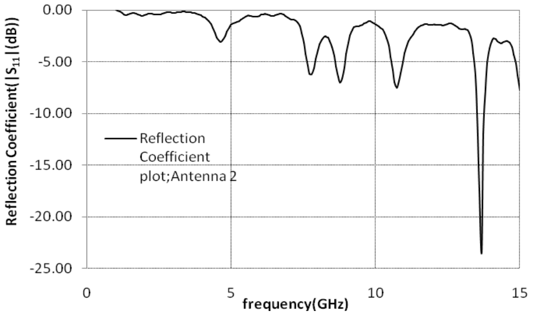
Total number of individuals (population size, *TI*) is an important parameter that required careful selection. As large number of individuals requires evaluation of more fitness values due to thorough exploration of the solution space, leading to huge computational time. Whereas relatively very small population of individuals may not sufficiently explore a solution space. Few of the results found in published literature shows that a population of individuals of the order of 15 is optimal. The momentum factors ($M_d$ and $M_s$) are helpful in restricting the individual's dose and state inside the defined search space without checking the health on every day. Depending upon the probability of recovery (α), the treatment is given to individuals in the population. The lower value of α (0.2) helps in recovering most of the individuals.

## VI. Validation Of Results

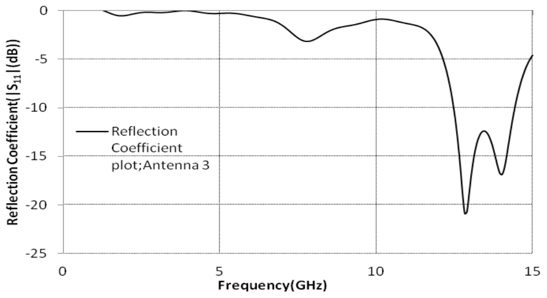
Total six antennas have been simulated and tested. The reflection coefficient plots for these antennas are shown in the Fig. 9 (a) to Fig. 9 (f). The fabricated antenna is shown in the Fig. 10. The numerical response of these antennas is listed in the Table III. Computational time taken by optimizer in each case is also listed in Table III.



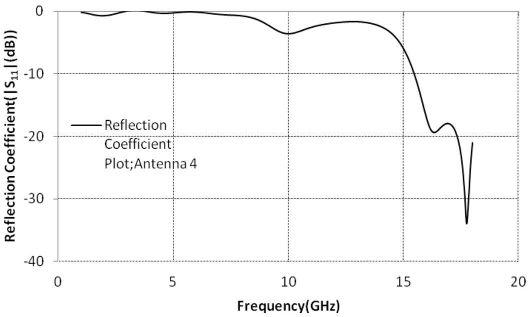
(a)



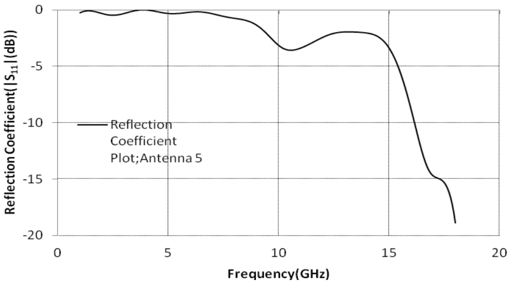
(b)



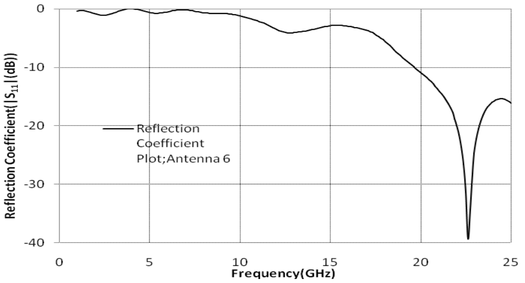
(c)



(d)



(e)



(f)

Fig. 9. Reflection coefficient plots.

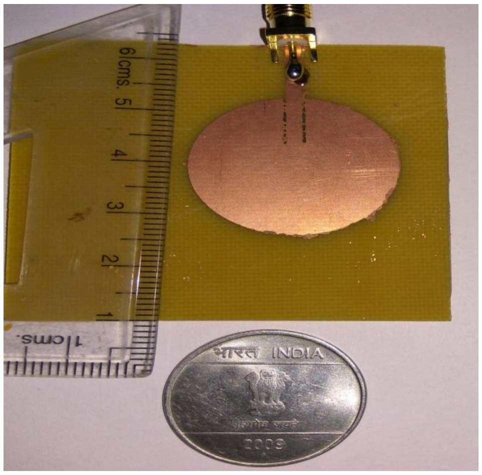


Fig. 10. Fabricated antenna picture.

TABLE III. Optimizer Performances

| Ant. No. | Input to the optimizer, $f_r$ (GHz) | Optimizer response | | Computational time (sec) |
|---|---|---|---|---|
| | | Radius, $a$ (mm) | Inset-feed depth, $y_0$ (mm) | |
| 1 | 11 | 13.49 | 9.308 | 120 |
| 2 | 13 | 8.886 | 6.131 | 133 |
| 3 | 14 | 5.226 | 3.606 | 111 |
| 4 | 16 | 4.08 | 2.815 | 93 |
| 5 | 18 | 3.866 | 2.668 | 143 |
| 6 | 22 | 3.191 | 2.201 | 131 |

The optimizer performances can be estimated numerically from the Table IV. The amount of error between simulated and computationally calculated results is well within 2%.

TABLE IV. Optimizer Performances

| Ant. No. | Input variable parameters (mm) | | Simulator Output $f_r$ (GHz) | Matlab Computational Output $f_r$ (GHz) | % Error |
|---|---|---|---|---|---|
| | **a** | **$y_0$** | | | |
| 1 | 13.49 | 9.308 | 11.22 | 11.42 | 1.43 |
| 2 | 8.886 | 6.131 | 13.6 | 13.4 | 1.47 |
| 3 | 5.226 | 3.606 | 14.02 | 14.2 | 1.28 |
| 4 | 4.08 | 2.815 | 16.3 | 16.65 | 2.14 |
| 5 | 3.866 | 2.668 | 18 | 18.06 | 0.34 |
| 6 | 3.191 | 2.201 | 22.6 | 22.29 | 1.37 |

The optimizer performance has been compared with the computationally calculated results. For the computational results, the MATLAB code were developed using the equations, based on the resonance frequency along with the dimension of the patch and feed location (Eq. 3- Eq. 6). From the numerical results mentioned in the Table IV, the accuracy of the optimizer can be estimated. In order to validate results with the measured antennas, one of the antennas was fabricated in the laboratory. The process of fabrication involves few steps described as follows. First optimized parameters of the antenna, viz. antenna no. 1; a = 13. 49 mm and $y_0$= 9.308 mm, were taken along with the constant geometrical parameters; $\varepsilon_r$ = 4.4, $h$ = 1.6 mm and loss tangent 0.025. A layout was drawn using corel draw (V8) (Fig. 11 and Fig. 12). Using the steps as shown in the Fig. 13, antenna was fabricated in the RF and microwave laboratory. Then measurement activity was performed with the help of vector network analyser (Fig. 14). The experimental setup for one of the antenna has been shown in the Fig. 15.

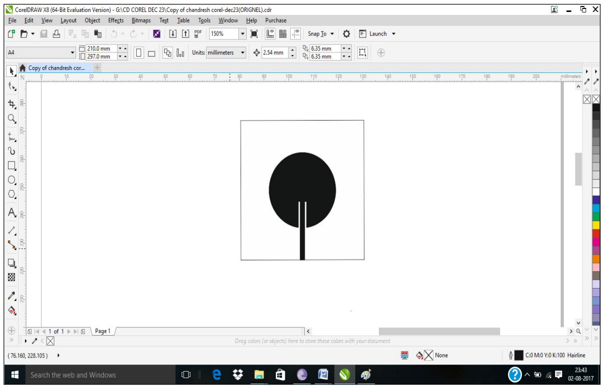


Fig. 11. Corel draw layout.

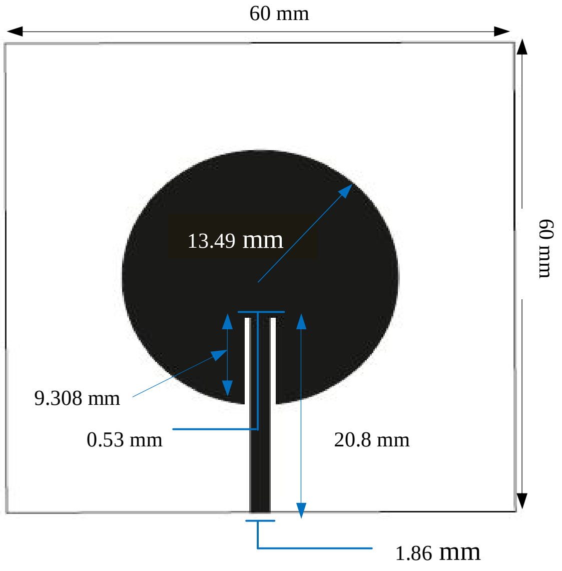


Fig.12. Parameter values of antenna no.1 in Corel Draw.

The graphical view of the simulated and measured reflection coefficients plots is shown in Fig. 16 and Fig. 17. The close resemblance between plots also validates our methodology. The Fig. 18 below depicts the smith chart for the impedance plot of the simulated as well as measured antenna (ant. no. 1). From the chart also close resemblance can be found between both. The Fig. 19 represent the far field 2D directivity pattern plot for the one of the simulated antennas (ant. no. 1).

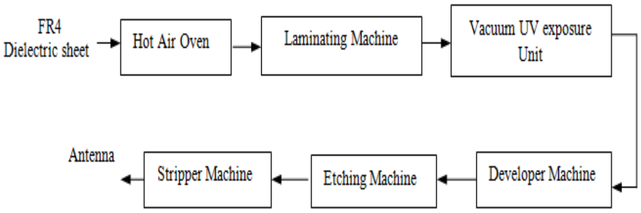


Fig. 13. Antenna fabrication process.

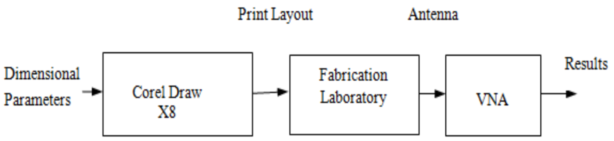


Fig. 14. Measurement steps of antenna.

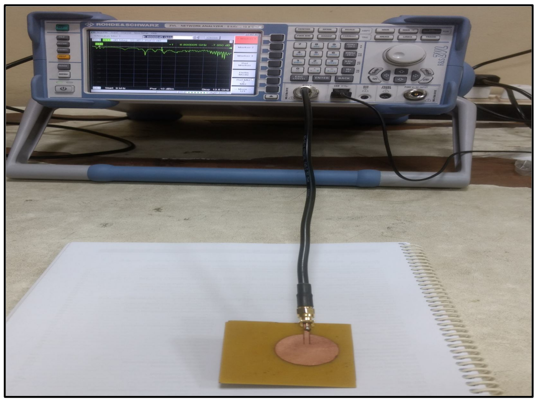


Fig.15. Antenna testing using VNA.

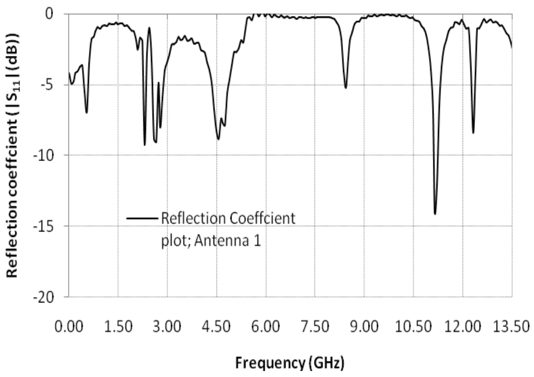


Fig. 16. Plot of simulated reflection coefficient for ant. no. 1.

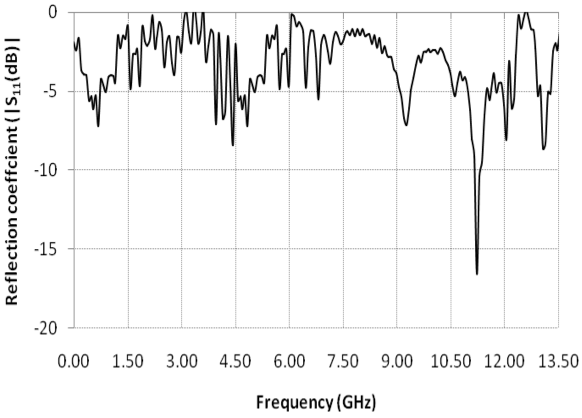


Fig. 17. Plot of measured reflection coefficient for ant. no. 1.

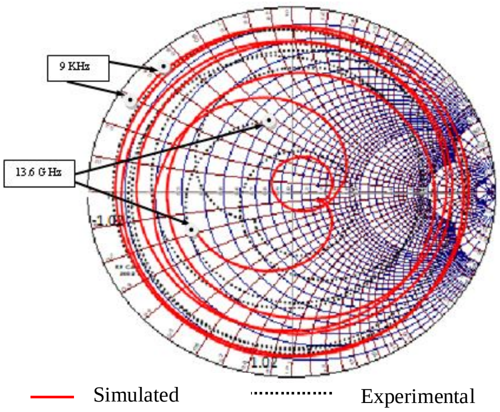


Fig.18. Smith chart impedance plot for ant. no. 1.

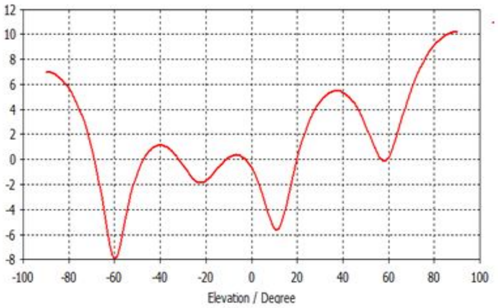


Fig.19. 2-d directivity plot.

## VII. CONCLUSIONS

In this paper, a fast and flexible approach for designing inset feed micro strip circular patch antenna using nature inspired optimization has been presented. A SIMBO-T whose fitness function is calculated to find the design dimensions of circular patch antenna. The Dose and state equations of SIMBO-T algorithm has been modified for the circular parch dimensions. The developed optimization tool has been utilized to design several antennas. In the proposed work, the performance of SIMBO-T has been evaluated in terms of quality of optima number of times hitting stopping criterion, convergence. One of the antennas was fabricated and measured. The realized antenna was found very much close to expectations. As there is an error within 5 % between the resonance frequencies calculated through simulated (11.22 GHz) and measured (11.15 GHz) reflection coefficient plots. The developed approach is very much flexible in the sense that the antenna designer has to input the required resonance frequency only within the specified range and the optimizer produces the design dimensions of the antenna as the output. It is very fast convergence and accurate method, which can replace an old technique in the coming days.

Since the parameters used in SIMBO-T changes dynamically as the algorithm progresses. Therefore SIMBO-T is able to cope with complex multimodal landscape efficiently. SIMBO-T seems to be suitable to meet the needs of parallel computer architecture due to its unique feature of no relationship of individual with the other individuals in each generation.

The major advantages of SIMBO-T technique is easy implementation, fast convergence and better accuracy of global optima. The computational time is the bottle neck of this optimization technique. SIMBO-T algorithm doesn't require more computational effort to achieve the global optima. In order to test the SIMBO-T, we have taken few performance parameters only like reflection coefficient and input impedance. Further the proposed optimization technique can be applied for more complex antenna structure like triangular, rectangular pentagonal, hexagonal etc. Though the technique has been applied for single layer antenna having only few geometrical parameters, however the structure can be expanded as a multilayer antenna structure having many patches and large number of variables. Proposed optimization technique can be tested for these cases as well. In our work, we have applied only SIMBO-T, most advanced version like SIMBO-V and SIMBO-Q can be also tested for these structures. Some more parameters (space parameters) like radiation pattern, gain, directivity etc. can also be taken care of and optimized.

## APPENDIX:PSEUDO CODES

```
Initialization of parameters
            $TI, TD, Fe, Co, fathead, NV, Dai, \alpha, PS, PH, M_d$ and $M_S$
for Day = 1:$TD$
            for i = 1:$TI$
                    Current_health (i) = Evaluate Fitness Function (S (i))
            end
               Update $PS$ and $PH$
                    $\Pr imary(Day) = (Fe * Co * fathead * NV * Dai) * \exp(-TD / Day)$
                        $R0(Day) = 1 - e^{(-\Pr imary(Day))}$
       Treatment (T)
           for m = 1:$TI$
                 If rand > $\alpha$
                   $Dose(m+1) = Dose(m) + Md + \Pr imary(Day) * rand *$
                                      $(1 - Current\_health(m) / rand * PH)$
                                  $+ R0(Day) * rand(Current\ health(m) - PH)$
                   $S(m+1) = S(m) * Ms + Dose(m+1)$
                 end
           end
end
```

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